The diameter of a cricket-ball is nearly 3 inches, and its weight 5·5 oz. The value of *a* for its motion is therefore 327 feet. Partly on this account, but more on account of its lower speed, a cricket-ball has its path much less affected by resistance than is that of a golf-ball. If we take its maximum initial speed as 130, the initial resistance is only about 1·6 times its weight; while for a golf-ball it rises to about 28-fold its weight. Their momenta are nearly equal, being about 45 and 50 respectively. But their kinetic energy is very different in the two cases, being 90, and 390, foot-pounds respectively. This, again, is in full accord with every-day experience. In the simple vernacular of the cricketer, a well-struck golf-ball would be characterized, at least for the first fifty yards or so of its course, as a "hot" one indeed!

The article may fitly close with a few remarks on another very prevalent fallacy:—viz. the belief that a golfer continues to guide his ball with the club long after it has left the tee. How any player who has ever "jerked" a ball (and who has not?) could maintain such an opinion is an inscrutable mystery. But it is a physical fact, established by actual measurement, that when a block of wood weighing over 5 pounds is let fall on a golf-ball (lying on a stone floor) from a height of 4 feet, the whole duration of the impact is less than 1/250 of a second. When it falls from a greater height the duration of impact is less. But if the elastic force which made the block rebound had been employed to move the golf-ball itself, whose weight is only 1/10 of a pound, (or 1/50 of that of the block) the operation would have occupied only 1/50 of the time; say the 1/12,500 of a second. In the case before us we are dealing with much greater speeds, and therefore with still smaller intervals of time. It is with veritable *instants* like these that we are concerned when driving a golf-ball. The ball has, in fact, left the club behind, before it has been moved through more than a fraction of its diameter.

Another way in which this important point can be made plain to anyone is as follows:—When two bodies impinge, the whole time of the mutual compression is greater than that which would be required to pass over the space of linear compression with the relative speed, but less than twice as great. And the time of recoil is greater than that of approach in the ratio 1 : *e*:—where *e* is the "coefficient of restitution" which, with hard wood and gutta-percha, is about 0·6 when the relative speed is very great. Hence the whole time of impact between the club and the ball is that in which the club, moving at 300 feet per second, would pass through about four times the linear space by which the side of the ball is flattened.

P. G. Tait.

THE WORKING EFFICIENCY OF SECONDARY CELLS.

Under this title a paper was contributed, at the recent meeting of the Institution of Electrical Engineers at Edinburgh, by Prof. Ayrton and Messrs. Lamb, Smith, and Woods, which contains some considerable additions to our knowledge of the subject of secondary cells. The cells on which the tests were made were of the 1888 E.P.S. type, and were charged and discharged at the maximum working currents, these being kept constant in value by hand and automatic regulation. In the most important series of tests the limits of volts employed was 2·4 volts for charge and 1·8 volt for discharge: it was found that a lower limit than this led to detrimental actions in the cells, with loss of active material.

The advantages of a constant current are that it is a nearer approximation to practical working conditions, and that the calculations are much simplified: in fact, the ampere efficiency is got by simply multiplying together the ratio of the charge and discharge currents and the ratio of the times occupied in charging and discharging. The true (or watt) efficiency was found by plotting time readings of the P.D., and taking the ratio of the areas of the curves thus drawn: this, multiplied by the ampere-efficiency, is the required true efficiency.

The first important point brought out in the paper is the importance of the resuscitating power possessed by accumulators. In an early set of tests, made on well-charged cells, the authors found a quantity efficiency of over 100 per cent. with correspondingly abnormal watt efficiency, and this, although the tests occupied five days, from which they conclude that, "if accumulators be well charged up before being tested, five days' continuous alternate charging and discharging with the maximum currents allowed by the manufacturers fails to give the normal working efficiency."

Since these results were so unsatisfactory, some method of avoiding drawing on a previous store had to be adopted. Some experimenters secured this condition by running down a cell, and then leaving it short-circuited for some time. In the present series of experiments the required condition was fulfilled as follows: the cells were continuously charged and discharged with regularity until the successive charges occupied exactly the same time, and successive discharges did also. When the cells arrive at such a "steady state," it can evidently be taken that no drawing on a previous store is taking place. It was, then, under these conditions that the experiments were made.

As such a long series of experiments would entail much labour in keeping the current constant, an automatic regulator was devised to effect this, together with further automatic devices for breaking circuit when the P.D. reached any predetermined value, and for telling the time when such break occurred. The authors state that these apparatuses worked to within ½ per cent. of the supposed limits. Throughout the investigation D'Arsonval instruments were adopted, and by suitably suspending the movable coil, the calibration curve was absolutely a straight line. In these further tests the same instrument was used for measuring volts and amperes, the requisite alteration of circuit being made by a rocking commutator. The volts were read frequently, and curves of P.D. plotted. With this apparatus and measuring instruments, the curves given below for steady state of charge and discharge between limits of 2·4 and 1·6 volts per cell were obtained.

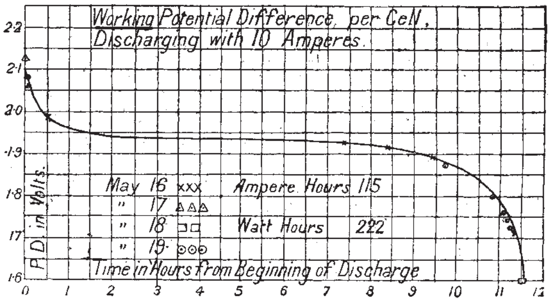

Fig. 1.

From these curves efficiencies of 98·3 per cent. for current, and 86·5 per cent. for energy, were obtained.

It was then found that 1·6 volt was far too low a limit to take, as scaling of the plates took place, and so (as mentioned above) limits of 1·8 and 2·4 volts were adopted. After several charges and discharges, the cells arrived at a "steady state" again, the successive times being as follows:—

Discharges. h. m.		Charges. h. m.
10 10	... ...	11 38
10 10	... ...	11 37
10 11	... ...	11 37

"showing to what an absolutely definite state cells arrive after a definite cycle of charge and discharge between fixed limits has been repeated continuously, without interruption, for some weeks." These results give an ampere efficiency of 97·2 per cent. and an energy efficiency of 87·4. These they adopt as the true steady values for this type of cell, and this shows a working storage capacity of 21,380 foot-pounds per pound of plate.

The next point brought out is the effect of rest on a charged cell; the cells were fully charged, and allowed to rest in that state, being well insulated from everything. In every case the first discharge and charge show a marked falling off in capacity and efficiency, the latter being reduced to 58 per cent. in one case cited. A point of some theoretical interest is brought out in connection with the curves obtained in this part of the investigation: a normal discharge curve *falls* rapidly at first, then remains constant, and falls again, as shown in Fig. 1; the first discharge curve, *after rest*, *rises* at first instead of falling.

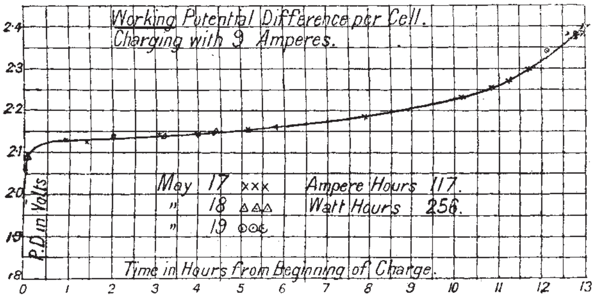

FIG. 2.

The authors sum up this part of their paper as follows:—

"From all that precedes, it follows that the previous history of an accumulator produces an enormous effect on its efficiency. If, for example, an E.P.S. accumulator be over and over again carried round the cycle of being charged up to 2·4 volts per cell and discharged down to 1·8 volt per cell, the charging and discharging currents being the maximum allowed by the makers—viz. 0·026 ampere per square inch in charging, and 0·029 ampere per square inch in discharging—the '*working efficiency*' thus obtained may be 97 per cent. for the ampere-hours and 87 per cent. for the watt-hours. If, on the contrary, the cell be constantly charged up before being tested, then for the first few charges and discharges between the above limits, and with the same current-density in charging and discharging, even the *energy* efficiency may be as high as 93 per cent.; whereas, if the accumulator has been left for some weeks, then, although it was left charged, the energy efficiency for the first few charges and discharges will be as low as 70 per cent.

"While, on the one hand, our tests show that continued rests of a charged accumulator appear to be far more serious for the accumulator than we had previously imagined, the working efficiency appears to be higher than has hitherto been supposed, since we believe that about 84 per cent. efficiency in the watt-hours is all that the advocates of accumulators have claimed for them."

The next section deals with some points connected with the chemical action, and it is shown that the actual amount of SO_3 liberated on charge per ampere-hour, as calculated from the change of specific gravity, agrees well with the ordinary simple formulæ. We understand a further paper on this point may probably be forthcoming later on, which will deal with the chemical changes going on in the plugs at various points in the charge and discharge. As this involves the partial destruction of a cell, and a lengthy series of analyses, it was not found possible to put it in the present paper.

The next point brought out is of considerable interest: during several charges and discharges, the difference of temperature between the working cell and a neighbouring idle cell was observed frequently, and it was noticed that the cell cooled during discharge, in spite of the heat generated by the resistance. This was simultaneously observed by Prof. Duncan in America. The general shape of the temperature curves is given below.

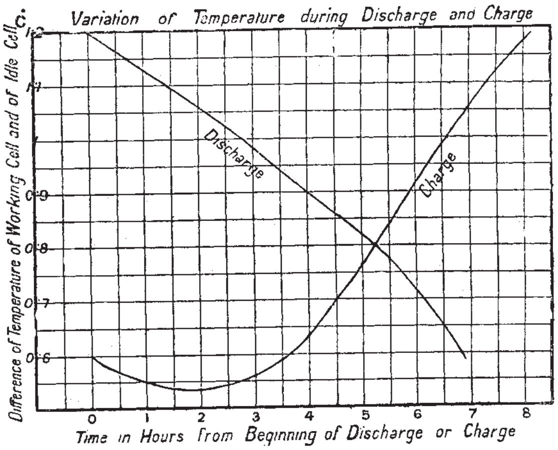

FIG. 3.

From the mean excess of temperature of the cell the authors deduce the somewhat startling fact that 17 per cent. of the energy put into the cell is wasted by radiation and convection. As they found that but 13 per cent. is really lost, it follows that the rest of the energy must be given by some sort of primary battery action, so that they consider an accumulator is partly a reversible and partly an irreversible battery. In this way the gradual deterioration is accounted for. Possibly this may partly account for the short life of small accumulators.

The concluding section deals with the question of the resistance of cells when brought to a steady state. The method adopted is that of introducing an opposing E.M.F. in the voltmeter circuit when time readings of the E.M.F. are being taken on breaking circuit. From these the E.M.F. at breaking circuit is found by producing backwards to zero, and the P.D. being also measured, together with the current before breaking, we can get the resistance at the moment of break. The method is delicate, and seems to have yielded good results; but lack of time has prevented this section being dealt with with other than one set of current values.

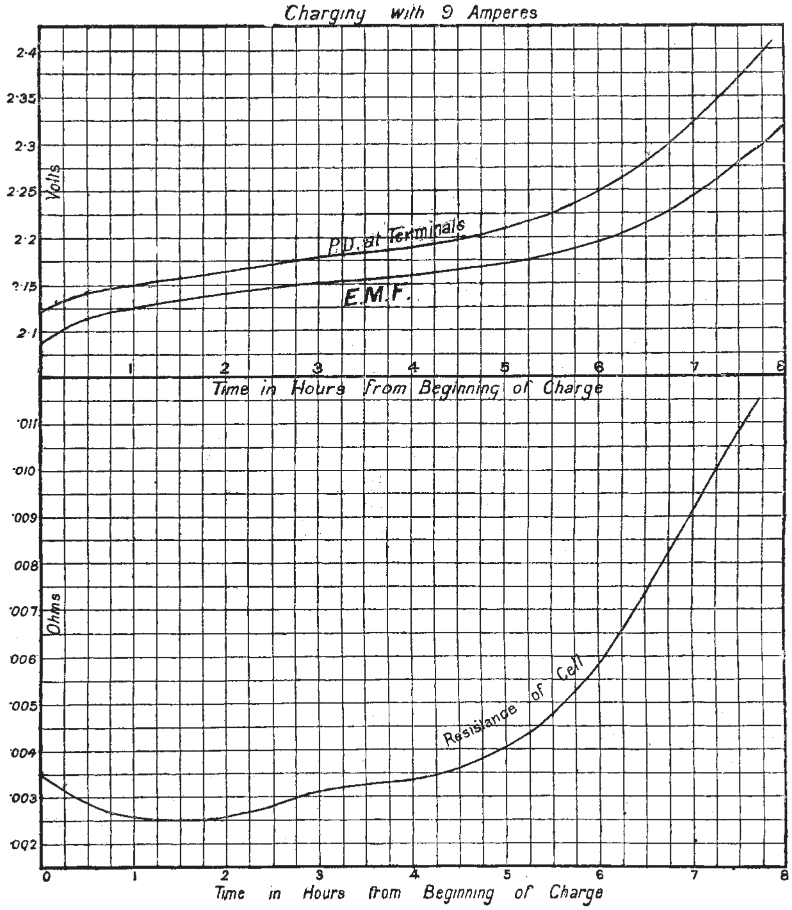

FIG. 4.

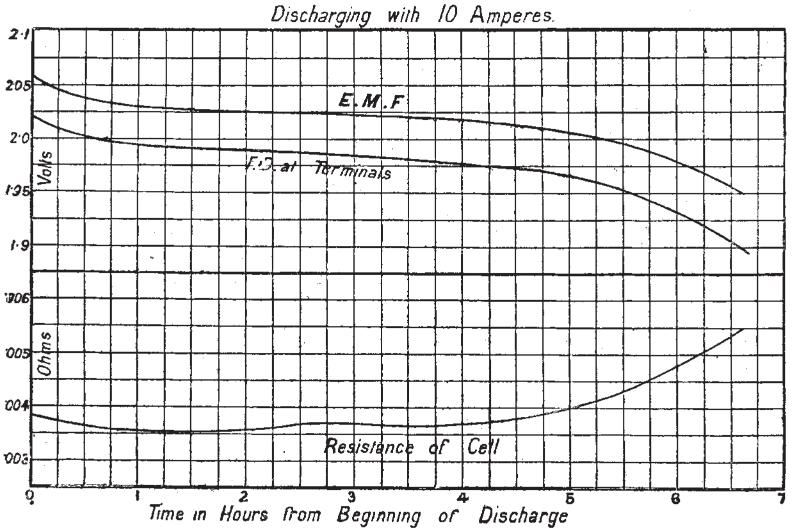

FIG. 5.

We print the curves given in the paper for resistance on charge and discharge.

The paper seems, on the whole, a useful and suggestive contribution to the current knowledge on the subject.